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NOTE

Absorption spectra analysis of exposed FWT-60 radiochromic film

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Abstract

The visible absorption spectra of Radiachromic FWT-60 radiochromic film have been investigated to analyse the dosimetry characteristics of the film. The film is radiation sensitive to high absorbed doses. The visible absorption spectra of this film when exposed to photon radiation show a peak at 605 nm which is stable over the dose range of 0 Gy to 20 kGy. The radiation sensitive absorption spectra are present over the wavelength range of approximately 500 nm to 660 nm. Negligible dose response is seen in the infrared region or the UV region of wavelength readout. Variation of sensitivity of response can be achieved by varying the wavelength of readout with the maximum measured response of 0.077 OD units per kGy. The film can be an ideal dosimeter for areas where high dose levels need to be measured.

Introduction

Radiochromic film dosimetry in radiation detection can depend on many parameters. One of the major contributing factors can of course be the type of radiochromic film used such as Gafchromic (ISP Technologies) (Butson *et al* 2003), Radiachromic (FWT technologies) (Young *et al* 1999) or B3 windose (GEX corporation) (Miller *et al* 2003). One of the largest contributing factors is the visible absorption spectra of the radiochromic film and as such the change of wavelength used for readout. The absorption spectra for various types of films have been reported previously. Films such as the well-known Gafchromic media produce distinct visible absorption peaks at specific wavelengths around 676 nm and 618 nm (Niroomand-Rad *et al* 1998) thus producing a blue visible colour upon irradiation. FWT-60 radiochromic film also produces a blue colour upon irradiation, however, there is a visible different shade of blue compared to Gafchromic film. This short note investigates

the visible light absorption spectra for FWT-60 radiochromic film after being exposed to high level x-ray radiation.

Materials and methods

The FWT-60 radiochromic dosimeters are composed of hexa(hydroxyethyl) pararosaniline nitrile. The matrix that holds the dye is nylon (Miller *et al* 1988). The film has a density of approximately 1.15 g cm^{-3} and a composition (by mass) of 63.7% C, 12.0% N, 9.5% H and 14.8% O. It has a physical thickness of 0.05 mm (Larson 2003) and is easily handled with the use of a plastic or paper tag, stuck to the side of the film. FWT-60-20 F radiochromic film, lot number 1045, was used for the visible absorption spectra study. For dose delivery, the films were sandwiched in a 10 cm $\times$ 10 cm $\times$ 5 cm block of solid water (Constanitinou *et al* 1982) with the film irradiated at a depth of 1.5 cm within this phantom. The phantom was placed at the central axis of a 6 MV x-ray beam at the position of the Mylar cross hairs on a Varian 2100C linear accelerator. Thus the films were 54 cm from the x-ray source. This was performed to increase the dose delivery rate. Radiation doses of approximately 1 kGy up to 20 kGy (estimated using inverse square law corrections to 100 cm SSD calibration data) were delivered to the film, which was placed perpendicular to the central axis of the beam. In each case, five films were exposed to the quoted dose level. Precautions in the handling of FWT-60 radiochromic film outlined by Butson *et al* (2003) were performed. The film during storage and film analysis was kept at temperatures of 22 °C $\pm$ 2 °C and humidity 30%–70% which reduces effects of time, temperature and humidity-dependent evolution and readout (Ningnoi and Ehlermann 1994, McLaughlin *et al* 1996) of the absorption spectra of the film. The film was only removed from a light tight envelope during irradiation and readout to reduce any effects of ambient light (Butson *et al* 1998). The film was cut into 1 cm $\times$ 3 cm strips for analysis for easy insertion into the spectrophotometer. The absorption spectra results were measured using a Shimadzu UV-160 UV-visible recording spectrophotometer (Butson *et al* 2002). Wavelength range of analysis was from 300 nm to 1100 nm in 2 nm to 10 nm steps. The Shimadzu UV-160 has a spectral bandwidth of 3 nm with an accuracy of $\pm$0.5 nm. The film was held in a quartz holding container during analysis. Spectra data were then analysed to calculate sensitivity values at various specific wavelengths.

Results and discussion

Figure 1 shows the absorption spectra for FWT-60 Radiachromic film in the UV, visible and infra red wavelength regions (300 nm–1100 nm). Results are given for films ranging in applied doses of 0 Gy to 20 kGy produced by a 6 MV x-ray beam. Each absorption spectrum shown is the average of five films measured. Also shown is the mean error in measurements. As can be seen the absorption spectra for the film produce one main absorption peak. The peak is located at 605 nm and does not shift with increase in dose as is the case for MD-55 Gafchromic film (Niroomand-Rad *et al* 1998). The film produces a change in optical density with radiation dose within the visible light region ranging from approximately 500 nm up to 660 nm. This produces the pure blue colour seen with increased radiation exposure. No changes in absorption properties were seen in the ultraviolet and infrared regions of the film with increased radiation exposure up to 20 kGy. By observing the main absorption peak in more detail a skewed peak at 605 nm is seen with a faster drop-off in absorption on the higher wavelength side than the lower wavelength side of analysis. If analysis is performed to measure dose sensitivity at specific wavelengths a sensitivity table can be created as shown

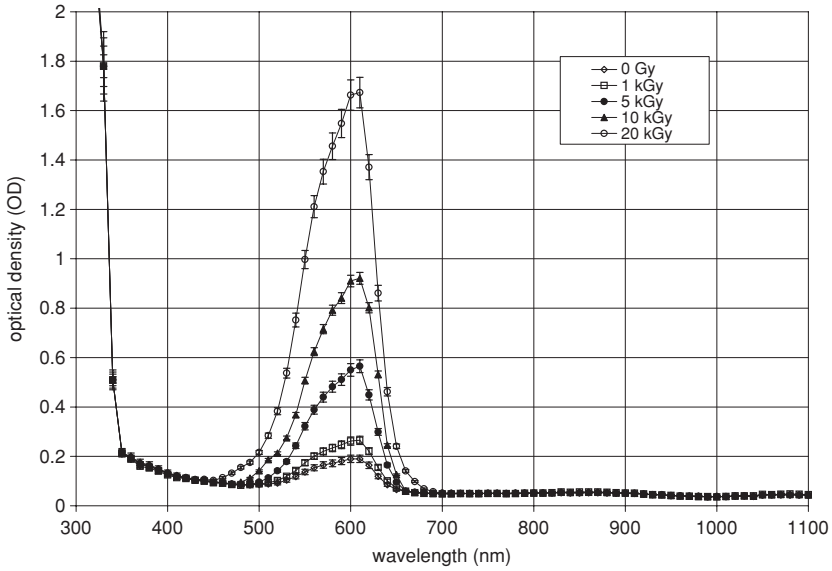

Figure 1. Visible absorption spectra for Radiachromic FWT-60 radiochromic film when exposed to 6 MV x-rays. Of interest is the absorption peak located at 605 nm and the relatively negligible response to x-ray radiation seen in the infrared and ultraviolet readout range.

Table 1. Net OD response to dose at specific wavelength of analysis.

Wavelength (nm)	Absorbed dose (kGy)			
	1	5	10	20
640	0.016	0.08	0.16	0.36
620	0.057	0.285	0.638	1.19
610	0.075	0.37	0.731	1.466
605	0.077	0.376	0.74	1.477
600	0.072	0.36	0.72	1.39
590	0.066	0.335	0.674	1.267
570	0.055	0.275	0.55	1.04
550	0.037	0.185	0.37	0.617

in table 1. Results show that the highest dose sensitivity is recorded at the absorption peak (605 nm) with a relatively linear dose to OD response up to 20 kGy absorbed dose. This dose to OD response decreases at higher wavelengths but remains a relatively linear response.

Figure 2 shows the net optical density response of the FWT-60 Radiachromic film for the doses measured. This is produced by a direct subtraction of our 0 Gy optical density results for each film piece from the exposed film OD results. This highlights the actual sensitivity response of the film to dose at the recorded wavelengths with the negligible response below approximately 500 nm and above 660 nm. As the absorption spectra of this film vary quite considerably from Gafchromic Radiochromic film, a densitometer dedicated to Gafchromic film readout may not necessarily be useable for FWT-60 film analysis. Gafchromic film media produce a wavelength peak at 676 nm. As such, dedicated densitometers often have their light source matched to this wavelength or a wavelength close to this peak such as

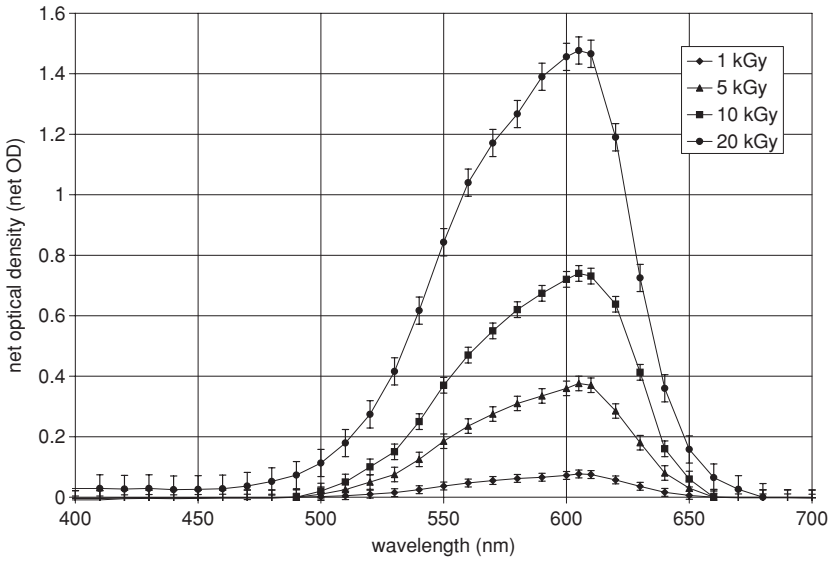

Figure 2. Net optical density response of the FWT-60 radiochromic film for radiation doses of 6 MV x-rays up to 20 kGy.

at 660 nm (Carolan *et al* 1997). If a densitometer using these wavelengths of analysis was used a negligible change in OD would be seen for any dose level measured. A HeNe light source which is another common wavelength of analysis for Gafchromic film is positioned at 632.8 nm. This value lies within the sensitive region of analysis for FWT-60 film but is not located near the peak. As such lower sensitivity would be recorded. For accurate measurement of absorbed dose with the highest sensitivity, a densitometer able to read at 605 nm or close by is recommended.

Conclusion

Radiachromic FWT-60 radiochromic film provides an adequate and quantitative measure of radiation absorbed doses for high levels of x-ray radiation dose. A relatively linear response is seen in radiation absorbed dose versus net optical density at most wavelengths of analysis in its sensitive range. An absorption peak is located at 605 nm which is the optimal wavelength of analysis for dose sensitivity and the radiation sensitive absorption range is approximately 500 nm to 660 nm. A dedicated Gafchromic film reader which is optimized for Gafchromic film readout with a light source output located around the 676 nm absorption peak would not be useful for FWT-60 film readout. A dedicated reader with wavelength near 605 nm would be recommended for the analysis of FWT-60 radiochromic film.

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